



Spaced Out Sports

Let's Play Space Ball

Objective

The students will investigate Newton's Laws of Motion by applying constant and differentiating forces to a "Space Ball" during a simulated game of football.

Description

Student teams will view video clips of three National Football Players discussing and demonstrating how they use Newton's Laws of Motion while playing their positions. Using these examples, your students will apply these laws of motion by accelerating a Space Ball toward an opposing team to score a touchdown. Then, using a Paper Football, a student will use Newton's Laws of Motion to kick the Paper Football through a Goal Post to score an extra point. Finally, the students will discuss Newton's Laws of Motion as it relates to their Space Ball game, make predictions, and compare their game to videos of similar activities performed on the International Space Station (ISS).

Materials

- 2 – One liter bottles
- Colored construction paper
- One sheet of notebook paper
- Scissors
- Cellophane tape (any classroom tape will work)
- Masking tape or colored tape – to mark the center of ball and playing field
- Meter stick
- 2 – Fishing lines (3 meters long each)
- Tongue depressors or short dowel rods
- Safety goggles
- Whistle (*optional*)
- *Spaced Out Sports* video clips



Newton's Second Law of Motion is about to be tested as New Orleans Saints linemen use their combined inertia to block the accelerating mass of the other team.

Spaced Out Sports

Management

Prepare your students for the Space Ball game by reviewing Newton's Laws of Motion (see *Newton's Laws of Motion Introduction* brief). Next, explain the Rules of Space Ball:

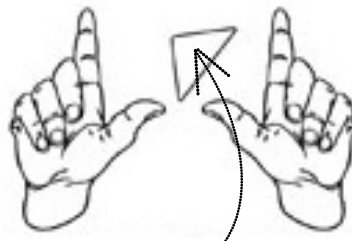
Rules of Space Ball



(1) Each Team will consist of 6 players – 5 Linemen/ Linewomen and a Kicker with no Quarterback. (2) Each team will select one of their six players to be their Field Goal Kicker for the entire game. The remaining members will be Linemen. (3) The game will consist of four 3 minute quarters with no time outs, no time outs for string breakage, - tied games remain a tie. (4) To score, the

Offense Linemen must push the center of the Space Ball past the center of the table onto the Defensive teams half of a table. The Defense Linemen can also score a Safety by pushing the tip (nozzle end) of the Space Ball past the Field Goal Line of the opposing team. (5) No team member can cross the center line of the table in an attempt to score.

(6) Once either team scores a Touchdown or Safety, the Kickers from both teams come to the table. Then the scoring team's kicker will attempt to kick a Paper Football through the goal post of the opposing team for an extra point (ball is kicked from the field goal line). (7) The opposing team then gets possession of the ball. After the Referee gives the signal, the team can begin pushing it toward the other team to try and score.



Points for Scoring: Touchdown – 6 points, Safety – 2 points, Field Goal – 1 point

The Head Referee for the game is the classroom teacher. If additional referees are needed, the classroom teacher can appoint a small number of students to assist.

(a) Before the game, the Offensive Linemen will each be assigned a number between 1 and 5, and then Defensive Line will be assigned the same numbering 1 - 5. (b) The Referee (classroom teacher) will randomly select two numbers from a cup for the assignment of the Offensive Line (e.g. 1 & 5) for the 1st Quarter. Then the Referee will replace the numbers into the cup and randomly select two numbers for the Defensive Line (e.g. 2 & 3) for the 1st Quarter. (d) *After each 3 minute Quarter the Referee will randomly select new replacement linemen for each team from the cup of numbers.*

Example: Defensive Lineman (#5) will hold one end of the Space Ball line to pull against Offensive Lineman (#3). Defensive Lineman (#1) will hold one end of the Space Ball line to pull against Offensive Lineman (#2).

Standards

National Science Education

Standards Unifying Concept and Processes

- Evidence, models, and explanation
- Science as Inquiry
- Abilities necessary to do scientific inquiry
- Physical Science
- Motions and Forces
- History and Nature of Science
- Science as a human endeavor

Principles and Standards for School Mathematics

Number and Operations

- Understand numbers
- Understand meanings
- Measurement
- Understand measurable attributes
- Apply appropriate techniques
- Data Analysis and Probability
- Formulate questions
- Select and use methods
- Develop and evaluate inferences
- Understand and apply
- Process Standards
- Problem Solving
- Communication
- Connections
- Representation

(e) Before the game, the Referee will ask one team's Kicker to select either "Heads or Tails" on a coin. Once the selection is made, the coin will be tossed. The winning team of the toss will select to either begin the game with possession of the Space Ball to start the game, Offense Linemen, (team begins the game pushing the Space Ball toward the other team) or to receive the Space Ball, Defense Linemen.

(I) The game **ALWAYS** begins with the tip (nozzle end) of the Space Ball resting at a complete stop on the Field Goal Line (10 cm from edge of table) of the team with possession of the ball (e.g. team scores a Touchdown, Field Goal, or Safety, the line breaks, etc.). (II) To begin play, the Head Referee will blow a whistle or says "go"; the teams will begin pulling the lines to push the Space Ball in order to score. (III) The goal is to get the ball past the center of the table to score a touchdown or push the tip (nozzle end) of the Space Ball past the Field Goal Line of the team in possession of the ball to score a Safety.

Background

For background information, refer to the *Newton's Laws of Motion Introduction* brief.

Explanation

The Space Ball works as a result of Newton's Laws of Motion. When the game begins the Space Ball is at rest (Newton's First Law). When the strings are pulled apart a force is applied to one side of the ball. This in turn causes the Space Ball to fly in the direction of the force (Newton's Second Law); while the other team tries to counter that force and cause the Space Ball to move in the opposite direction (Newton's Third Law).

When a Kicker sets up the Paper Football, the ball is at rest (Newton's First Law). When the football is flicked with a finger, a force is applied to the Paper Football causing it to travel toward the goal (Newton's Second Law).

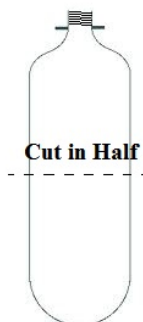
Procedure

Set up Playing Field

1. Measure the distance from end-to-end of a long table, or several small student desk pushed together. Find the center of the table (s) and apply a piece of colored tape to mark the center line between the two ends. This line is used to determine if a team crosses to score a touchdown.
2. Measure 10 centimeters from the end and apply a piece of colored tape to mark the Field Goal Line. The Kickers hands will be held on the 10 cm line to create a Field Goal with their thumbs pointing towards each other.

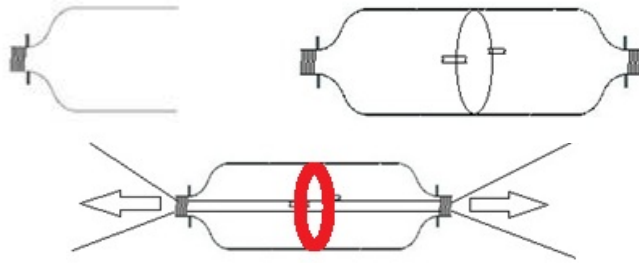
Construction of Space Ball

1. Carefully cut the 2 liter bottles in half using a pair of scissors.
2. Hold the two open ends of the bottles together so their necks are opposite of each other.
3. Tape the bottles together to form a football shape.



Construction of Space Ball

4. Thread the two 3 meters long fishing lines through the bottles.
5. Tie the open end of each line onto one of the tongue depressors or short dowel rods to make a handle. Then wrap tape around the line to secure to handle.
6. If time allows, cover Space Ball with colored construction paper.
7. Using colored tape or masking tape, mark the center of your ball by applying tape around the center section of the Space Ball. The colored tape is used to determine when a team crosses the center line of the playing table and scores a touchdown.

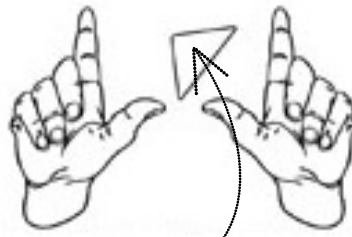


Construction of Paper Football

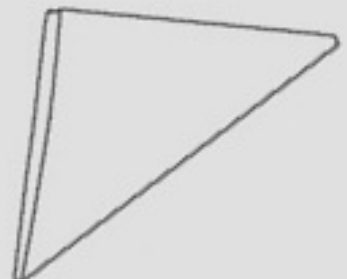
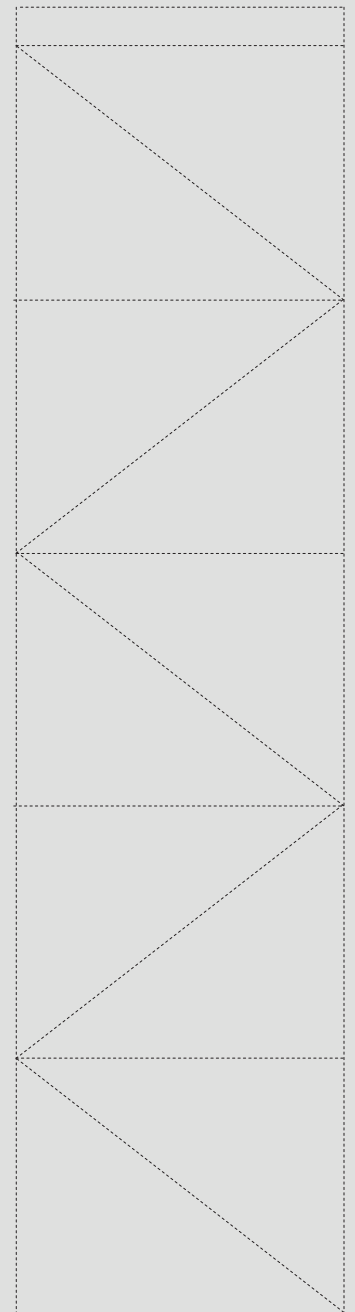
1. Using the supplied example (see right side of this page), fold a sheet of paper in half length-wise, making sure to give it a good crease. Then tear it in half along the fold.
2. Take one of the halves and fold it in half length-wise again. Once again, make sure to crease it good and tight.
3. Next, fold one end of that strip over on itself to make a triangle. Keep folding that triangle up and over toward the other end, always folding toward the paper.
4. Last, there should be a bit of extra paper left that doesn't make a complete fold at the end. Unfold the football opening and tuck that extra paper inside the football.

Construction of Field Goals

1. To form a Field Goal Post, the Kickers hands will be held together like uprights at the Field Goal line (10 centimeters from the end of table) with their thumbs pointing towards each other. (see diagram)
2. The kickers must wear safety goggles for eye protection — this will allow the players to keep both eyes open to determine whether the kick is successful.
3. Kicking from the Field Goal Line, the kicker gets a point for their team if they are successful in kicking their Paper Football between the opposing team's Field Goal.



Paper Football Example



Newton's Laws of Motion Introduction

Excerpt from *Rockets: Educator Guide With Activities in Science, Technology, Engineering and Mathematics* (EG-2008-05-060-KSC)

In his master work entitled *Philosophia Naturalis Principia Mathematica* (usually referred to as *Principia*), Isaac Newton stated his laws of motion. For the most part, the laws were known intuitively by rocketeers, but their statement in clear form elevated rocketry to a science. Practical application of Newton's laws makes the difference between failure and success. The laws relate force and direction to all forms of motion.

In simple language, Newton's Laws of Motion:

First Law

Objects at rest remain at rest and objects in motion remain in motion in a straight line unless acted upon by an unbalanced force.

Second Law

Force equals mass times acceleration
($f = ma$).

Third Law

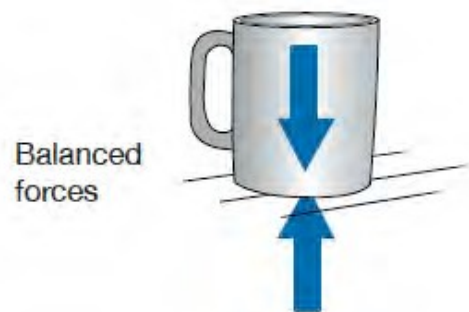
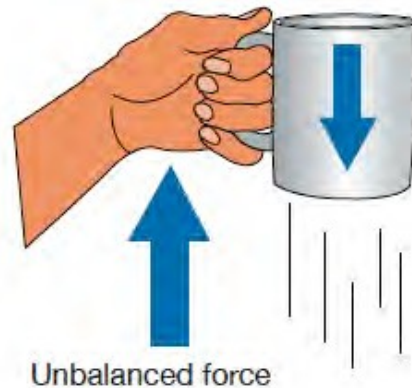
For every action there is an equal and opposite reaction.

Before looking at each of these laws in detail, a few terms should be explained.

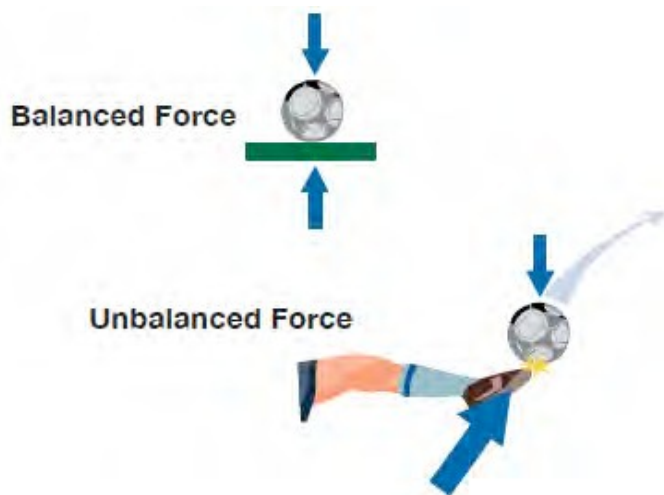
Rest and Motion, as they are used in the first law, can be confusing. Both terms are relative. They mean rest or motion in relation to surroundings. You are at rest when sitting in a chair. It doesn't matter if the chair is in the cabin of a jet plane on a cross-country flight. You are still considered to be at rest because the airplane cabin is moving along with you. If you get up from your seat on the airplane and walk down the aisle, you are in relative motion because you are changing your position inside the cabin.

Force is a push or a pull exerted on an object. Force can be exerted in many ways, such as muscle power, movement of air, and electromagnetism, to name a few. In the case of rockets, force is usually exerted by burning rocket propellants that expand explosively.

Unbalanced Force refers to the sum total or net force exerted on an object. The forces on a coffee cup sitting on a desk, for example, are in balance. Gravity is exerting a downward force on the cup. At the same time, the structure of the desk exerts an upward force, preventing the cup from falling. The two forces are in balance. Reach over and pick up the cup. In doing so, you unbalance the forces on the cup. The weight you feel is the force of gravity acting on the mass of the cup. To move the cup upward, you have to exert a force greater than the force of gravity. If you hold the cup steady, the force of gravity and the muscle force you are exerting are in balance.



Unbalanced force also refers to other motions. The forces on a soccer ball at rest on the playing field are balanced. Give the ball a good kick, and the forces become unbalanced. Gradually, air drag (a force) slows the ball, and gravity causes it to bounce on the field. When the ball stops bouncing and rolling, the forces are in balance again. Take the soccer ball into deep space, far away from any star or other significant gravitational field, and give it a kick. The kick is an unbalanced force exerted on the ball that gets it moving. Once the ball is no longer in contact with the foot, the forces on the ball become balanced again, and the ball will travel in a straight line forever. How can you tell if forces are balanced or unbalanced? If the soccer ball is at rest, the forces are balanced. If the ball is moving at a constant speed and in a straight line, the forces are balanced. If the ball is accelerating or changing its direction, the forces are unbalanced.



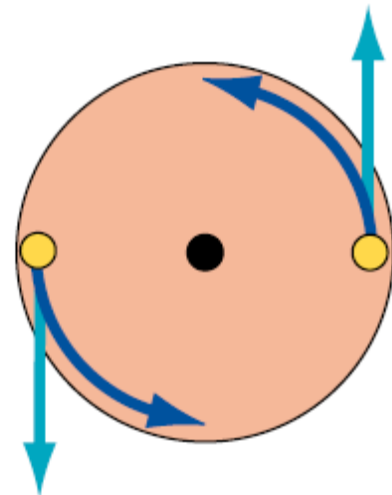
Mass is the amount of matter contained in an object. The object does not have to be solid. It could be the amount of air contained in a balloon or the amount of water in a glass. The important thing about mass is that unless you alter it in some way, it remains the same whether the object is on Earth, in Earth orbit, or on the Moon. Mass just refers to the quantity of matter contained in the object. (Mass and weight are often confused. They are not the same thing. Weight is a force and is the product of mass times the acceleration of gravity.)

Acceleration relates to motion. It means a change in motion. Usually, change refers to increasing speed, like what occurs when you

step on the accelerator pedal of a car. Acceleration also means changing direction.



This is what happens on a carousel. Even though the carousel is turning at a constant rate, the continual change in direction of the horses and riders (circular motion) is an acceleration.



Top view of two riders on a carousel. The carousel platform exerts unbalanced forces on the riders, preventing them from going in straight lines. Instead, the platform continually accelerates the riders in a counterclockwise direction.

Action is the result of a force. A cannon fires, and the cannon ball flies through the air. The movement of the cannon ball is an action. Release air from an inflated balloon. The air shoots out the nozzle. That is also an action. Step off a boat onto a pier. That, too, is an action.

Reaction is related to action. When the cannon fires, and the cannon ball flies through the air, the cannon itself recoils backward. That is a reaction. When the air rushes out of the balloon, the balloon shoots the other way, another reaction. Stepping off a boat onto a pier causes a reaction. Unless the boat is held in some way, it moves in the opposite direction. (Note: The boat example is a great demonstration of the action/reaction principle, providing you are not the one stepping off the boat!)

Newton's First Law

This law is sometimes referred to as Galileo's law of inertia because Galileo discovered the principle of inertia. This law simply points out that an object at rest, such as a rocket on a launch pad, needs the exertion of an unbalanced force to cause it to lift off. The amount of the thrust (force) produced by the rocket engines has to be greater than the force of gravity holding it down. As long as the thrust of the engines continues, the rocket accelerates. When the rocket runs out of propellant, the forces become unbalanced again. This time, gravity takes over and causes the rocket to fall back to Earth. Following its "landing," the rocket is at rest again, and the forces are in balance. There is one very interesting part of this law that has enormous implications for spaceflight. When a rocket reaches space, atmospheric drag (friction) is greatly reduced or eliminated. Within the atmosphere, drag is an important unbalancing force. That force is virtually absent in space. A rocket traveling away from Earth at a speed greater than 11.186 kilometers per second (6.95 miles per second) or 40,270 kilometers per hour (25,023 mph) will eventually escape Earth's gravity. It will slow down, but Earth's gravity will never slow it down enough to cause it to fall back to Earth. Ultimately, the rocket (actually its payload) will travel to the stars. No additional rocket thrust will be needed. Its inertia will cause it to continue to travel outward. Four spacecraft are actually doing that as you read this. *Pioneers 10 and 11* and *Voyagers 1 and 2* are on journeys to the stars!

Newton's Third Law

(It is useful to jump to the third law and come back to the second law later.) This is the law of motion with which many people are familiar. It is the principle of action and reaction. In the case of rockets, the action is the force produced by the expulsion of gas, smoke, and flames from the nozzle end of a rocket engine. The reaction force propels the rocket in the opposite direction.

When a rocket lifts off, the combustion products from the burning propellants accelerate

rapidly out of the engine. The rocket, on the other hand, slowly accelerates skyward. It would appear that something is wrong here if the action and reaction are supposed to be equal. They are equal, but the mass of the gas, smoke, and flames being propelled by the engine is much less than the mass of the rocket being propelled in the opposite direction. Even though the force is equal on both, the effects are different.

Newton's first law, the law of inertia, explains why. The law states that it takes a force to change the motion of an object. The greater the mass, the greater the force required to move it.



Newton's Second Law

The second law relates force, acceleration, and mass. The law is often written as the equation:

$$f = m a$$

The force or thrust produced by a rocket engine is directly proportional to the mass of the gas and particles produced by burning rocket propellant times the acceleration of those combustion products out the back of the engine. This law only applies to what is actually traveling out of the engine at the moment and not the mass of the rocket propellant contained in the rocket that will be consumed later.

The implication of this law for rocketry is that the more propellant (m) you consume at any moment and the greater the acceleration (a) of the combustion products out of the nozzle, the greater the thrust (f)